

X-ray Spectroscopic Studies of Low Dielectric Constant Parylene and Fluorinated Amorphous Carbon Films

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INTRODUCTION

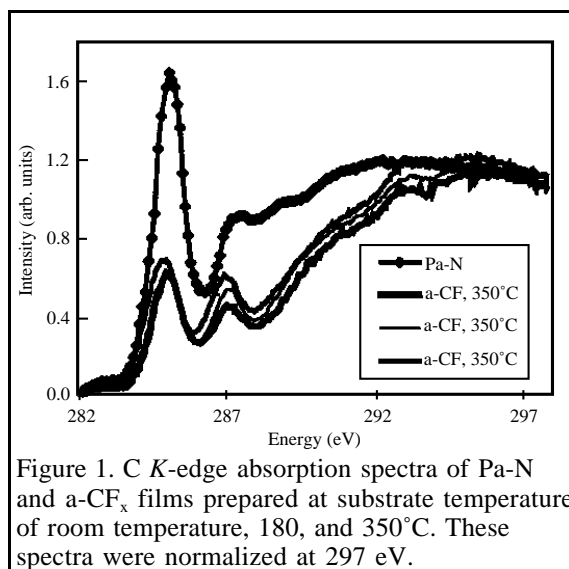
Currently there are intense industry-wide efforts in searching for new low dielectric constant (low- k) materials for use in future generations of ultralarge scale integrated circuits (ULSI). The new low- k (< 2.5) materials are expected soon to replace silicon dioxide ($k = 4$) as the interlayer in multi-level interconnect scheme, reducing substantially the interconnect RC delay in ULSI circuits. There are a number of requirements for the new low- k materials, such as low dielectric constant, thermal stability (400°C or higher), being electrically insulating, high mechanical strength, and good adhesion to neighboring layers. These stringent requirements have reduced the candidates to porous silica and a few carbon-based materials. Among them fluorinated amorphous carbon (a-CF_x) [1-3] and parylene [4,5] polymer thin films showed significant promise. Since these materials are new in IC applications, a complete understanding of the properties of these films is essential before they can be reliably used in future ULSI circuits. Some high-resolution X-ray spectroscopy studies have been performed on a-CF_x and parylene polymer thin films [6].

EXPERIMENT

The experiments of C $1s$ absorption and $K\alpha$ emission were performed at beamline 7.0 at ALS, LBNL. The beamline comprises a 99-pole, 5 cm period undulator and a spherical-grating monochromator [7]. XAS spectra were obtained by measuring the total electron yield from the sample. The resolution of the monochromator was set to 0.15 eV at C $1s$ absorption edge. The XAS spectra were normalized to the incident photon current using a clean gold mesh to correct for intensity fluctuation of the photon beam. The XES spectra were recorded using a high-resolution grazing-incidence x-ray fluorescence spectrometer [8]. During the XES measurement, the overall resolution was about 0.5 eV for C $K\alpha$ emission.

RESULTS and DISCUSSION

Figure 1 shows the C $1s$ absorption spectra of Pa-N and three a-CF_x films grown at room temperature, 180°C, and 350°C. Detailed local bonding information of these new films can be obtained from comparing with existing literature on simple fluorocarbon molecules [MCI87,STO92].



In Figure 2 the C *K*-emission spectra of amorphous carbon, a-CF_x and Pa-N are shown. From comparing with a-C, the intensity centered around 275 eV is mostly due to C-C bands. More importantly, in the region of 282-285 eV there is little intensity in the spectra of Pa-N and amorphous carbon. The intensity in the spectra of a-CF_x is mostly due to F-induced states and due to the amorphous nature of the films. Since these states are at the top of the valence bands, this has important implications in the electrical properties of these a-CF_x films, it narrows the band-gap. Because the x-ray absorption spectra of a-CF_x and Pa-N films have similar threshold, we can argue that the band-gap of a-CF_x is about 2 eV smaller than that of the Pa-N. Again because the band edge is not well defined for amorphous films this conclusion is very qualitative. The effect of the core hole needs to be considered as well. Qualitatively this conclusion is supported by the fact that a-CF_x is not as good an insulator as Pa-N.

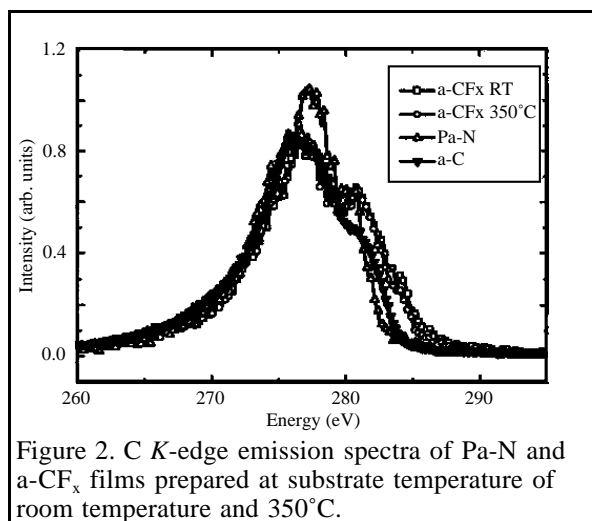


Figure 2. C *K*-edge emission spectra of Pa-N and a-CF_x films prepared at substrate temperature of room temperature and 350°C.

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